Claims

What is claimed is what is described in the text and illustrated in the drawings, including:

1. A method for optically measuring a sample, comprising:

directing one beam of guided light in a first propagation mode to a sample;

directing a first portion of the guided light in the first propagation mode at a location near the sample away from the sample before the first portion reaches the sample while allowing a second portion in the first propagation mode to reach the sample;

controlling a reflection of the second portion from the sample to be in a second propagation mode different from the first propagation mode to produce a reflected second portion; and

directing both the reflected first portion in the first propagation mode and the reflected second portion in the second propagation mode through a common waveguide into a detection module to extract information from the reflected second portion on the sample.

2. The method as in claim 1, wherein the first propagation mode and the second propagation mode are two polarization modes that are orthogonal to each other.

3. The method as in claim 2, wherein the first propagation mode and the second propagation mode are two orthogonal linear polarization modes.

4. The method as in claim 2, further comprising using a polarization rotator to cause the reflected second portion to be in the second propagation mode.

5. The method as in claim 2, further comprising using a Faraday rotator to cause the reflected second portion to be in the second propagation mode.

6. The method as in claim 2, further comprising using a quarter wave plate to cause the reflected second portion to be in the second propagation mode.

7. The method as in claim 1, further comprising using the common waveguide to both direct the guided light to the sample and to guide the

reflected first portion and the reflected second portion away from the sample.

8. The method as in claim 7, wherein the waveguide is a polarization maintaining waveguide.

9. The method as in claim 7, wherein the waveguide is a polarization maintaining fiber.

10. The method as in claim 1, further comprising using an input waveguide different from the common waveguide to direct the guided light to the sample.

11. The method as in claim 1, further comprising adjusting a relative phase delay between the reflected first portion and the reflected second portion.

12. The method as in claim 1, further comprising:

mixing energy of the first propagation mode and the second propagation mode in the detection module to produce a first optical signal and a second optical signal; and

detecting the first and second optical signals to extract the information of the sample.

13. The method as in claim 12, further comprising using a difference between the first optical signal and the second optical signal to extract the information of the sample.

14. The method as in claim 13, further comprising:

modulating a relative phase delay between the reflected first portion and the reflected second portion at a modulation frequency; and

using information on amplitudes of the difference at the modulation frequency and a harmonic of the modulation frequency to extract the information of the sample.

15. The method as in claim 12, further comprising:

separating different optical spectral components in the first optical signal;

measuring the different optical spectral components in the first optical signal;

separating different optical spectral components in the second optical signal;

measuring the different optical spectral components in the second optical signal; and

using the measurements to obtain a spectral response of the sample at a spectral component selected from the different optical spectral components.

16. The method as in claim 15, further comprising using an optical grating to separate the different optical spectral components in the fist optical signal by optical diffraction.

17. The method as in claim 1, further comprising controlling a spectral property of the guided light to the sample to obtain the information of the sample.

18. The method as in claim 1, further comprising using a tunable optical bandpass filter to select a center wavelength of a spectral range of the guided light to the sample to obtain a spectral response of the sample in the spectral range.

19. The method as in claim 1, further comprising:

adjusting a relative phase delay between the reflected first portion and the reflected second portion to a first value to measure a first signal associated with a first layer within the sample;

adjusting the relative phase delay to a second, different value to measure a second signal associated with a second layer within the sample; and

obtaining a ratio between the first and the second signals to extract information about a layer of the sample located between the first and the second layers.

20. The method as in claim 19, further comprising using a tunable optical bandpass filter to select a center wavelength of a spectral range of the guided light to the sample to obtain a spectral response of the layer of the sample located between the first and the second layers in the spectral range.

21. The method as in claim 19, further comprising using the ratio to measure a concentration of glucose in a dermis layer of a skin tissue.

22. The method as in claim 1, further comprising:

adjusting a relative phase delay between the reflected first portion and the reflected second portion to a value to select a layer from which a reflection component in the reflected second portion substantially matches the reflected first portion in phase;

modulating the relative phase around the value at a modulation frequency to obtain a measurement; and

processing the measurement to obtain information on the layer.

23. The method as in claim 22, further comprising:

using an optical delay device to produce and adjust the relative phase delay; and

using an optical delay modulator to modulate the relative phase.

24. The method as in claim 1, further comprising adjusting a relative lateral position between the second portion and the sample to direct the second portion to reach different locations on the sample to obtain information at the different locations.

25. A device for optically measuring a sample, comprising:

a waveguide to receive and guide an input beam in a first propagation mode;

a probe head coupled to the waveguide to receive the input beam and to reflect a first portion of the input beam back to the waveguide in the first propagation mode and direct a second portion of the input beam to a sample, the probe head collecting reflection of the second portion from the sample and exporting to the waveguide the reflection as a reflected second portion in a second propagation mode different from the first propagation mode; and

a detection module to receive the reflected first portion and the reflected second portion in the waveguide and to extract information of the sample carried by the reflected second portion.

26. The device as in claim 25, further comprising:

an optical delay device in an optical path of the reflected first and second portions to produce a relative phase delay between the reflected first and second portions; and

an optical delay modulator in the optical path of the reflected first and second portions to modulate the relative phase.

27. The device as in claim 25, further comprising an optical delay modulator in an optical path of the reflected first and second portions to produce a relative phase delay between the reflected first and second portions and to modulate the relative phase.

28. The device as in claim 25, further comprising a variable optical delay unit in an optical path of the reflected first and second portions to produce a variable relative phase delay between the reflected first and second portions, wherein the variable optical delay unit comprises:

a mode splitting unit to separate the reflected first portion in the first propagation mode and the second portion in the second propagation mode into a first optical path and a second optical path, respectively; and

a variable optical delay element in one of the first and the second optical paths to adjust an optical path length.

29. The device as in claim 28, wherein the variable optical delay element comprises:

a beam splitter to receive an input light beam to be delayed and to transmit a portion of the input light beam;

a transparent plate to receive transmitted light from the beam splitter and to rotate to change a path length of the transmitted light; and

a mirror to reflect light transmitted through the transparent plate back to the transparent plate to reach the beam splitter which reflects light from the transparent plate as a delayed output.

30. The device as in claim 28, wherein the variable optical delay element comprises:

an optical circulator to receive an input light beam to be delayed at a first port and to direct the input light beam to a second port,

a transparent plate to receive light from the second port of the optical circulator and to rotate to change a path length of the light transmitting therethrough; and

a mirror to reflect light transmitted through the transparent plate back to the transparent plate to reach the second optical port of the optical circulator which directs light from the second port to a third port as a delayed output.

31. The device as in claim 28, wherein the variable path length element comprises a fiber and a fiber stretcher engaged to the fiber to change a length of the fiber.

32. The device as in claim 28, wherein the variable path length element comprises two optical collimators and a movable retro-reflector in an optical path linking the two optical collimators.

33. The device as in claim 28, wherein the variable path length element comprises two optical collimators, and an optical plate and a reflector in an optical path linking the two optical collimators, wherein the optical plate rotates to change a path length of light.

34. The device as in claim 25, further comprising a variable optical delay unit in an optical path of the reflected first and second portions to produce a variable relative phase delay between the reflected first and second portions, wherein the variable optical delay unit comprises at least one tunable birefringent material and a fixed birefringent material.

35. The device as in claim 34, wherein the tunable birefringent material comprises a liquid crystal.

36. The device as in claim 34, wherein the tunable birefringent material comprises an electro-optic birefringent material.

37. The device as in claim 25, wherein the detection module comprises an optical detector.

38. The device as in claim 37, wherein the detection module further comprises an optical polarizer to receive and mix the reflected first and second portions to produce an optical output to the optical detector.

39. The device as in claim 38, further comprising an electronic unit to process output from the optical detector and process the output to extract the information of the sample.

40. The device as in claim 25, wherein the detection module comprises:

an optical polarizing beam splitter to receive and mix the reflected first and second portions that are respectively in the first and the second propagation modes to produce a first optical signal and a second optical signal;

a first optical detector to receive the first optical signal;

a second optical detector to receive the second optical signal; and

an electronic unit to receive and process outputs from the first and the second optical detectors to extract the information of the sample.

41. The device as in claim 40, wherein the first and second optical detectors are first and second detector arrays, respectively, the device further comprising:

a first grating to receive and diffract the first optical signal;

a first lens to focus different diffraction components in the first optical signal to different locations on the first detector array;

a second grating to receive and diffract the second optical signal; and

a second lens to focus different diffraction components in the second optical signal to different locations on the second detector array.

42. The device as in claim 25, wherein the probe head comprises a partial mode converter which sets the reflection from the sample in the second propagation mode.

43. The device as in claim 25, wherein the probe head comprises:

a partial reflector to reflect the reflected first portion of the input beam and to transmits the second portion of the input beam to the sample; and

a polarization rotator located between the partial reflector and the sample to change a polarization of the reflected second portion in controlling the reflected second portion to be in the second propagation mode.

44. The device as in claim 25, wherein the probe head comprises:

a partial reflector to reflects the reflected first portion of the input beam and to transmits the second portion of the input beam to the sample; and

a Faraday rotator located between the partial reflector and the sample to change a polarization of the reflected second portion in controlling the reflected second portion to be in the second propagation mode.

45. The device as in claim 25, wherein the probe head comprises:

a partial reflector to reflects the reflected first portion of the input beam and to transmit the second portion of the input beam to the sample; and

a quarter wave plate located between the partial reflector and the sample to change a polarization of the reflected second portion in controlling the reflected second portion to be in the second propagation mode.

46. The device as in claim 25, wherein the waveguide is a polarization maintaining waveguide.

47. The device as in claim 25, wherein the waveguide is a polarization maintaining fiber.

48. The device as in claim 25, further comprising:

a light source to produce the input beam;

an input waveguide to receive the input beam from the light source and to guide the input beam in the first propagation mode;

an output waveguide to receive the reflected first and second portions from the waveguide and to direct the reflected first and second portions to the detection module; and

an optical router coupled to the input waveguide, the waveguide, and the output waveguide and operable to direct light coming from the input waveguide to the waveguide and to direct light coming from the waveguide to the output waveguide.

49. The device as in claim 48, wherein the optical router is an optical circulator.

50. The device as in claim 48, wherein the optical router is a polarization preserving optical circulator.

51. The device as in claim 48, wherein the optical router comprises:

an optical circulator;

a first polarizing beam splitter in the waveguide to transmit light in the first propagation mode and to reflect light in the second propagation mode;

a second polarizing beam splitter in the output waveguide to transmit light in the first propagation mode and to reflect light in the second propagation mode; and

a bypass waveguide coupled between the first and the second polarizing beam splitters to direct the reflected second portion reflected by the first polarizing beam splitter to the second polarizing beam splitter which directs the reflected second portion into the output waveguide by reflection.

52. The device as in claim 48, further comprising a tunable optical filter located in one of the input waveguide, the waveguide, and the output waveguide to select a portion of the spectral response of the sample to measure.

53. The device as in claim 25, further comprising a tunable optical filter to filter the input beam to select a portion of the spectral response of the sample to measure.

54. The device as in claim 25, further comprising a tunable optical filter to filter the reflected first and second portions to select a portion of the spectral response of the sample to measure.

55. The device as in claim 25, further comprising a mechanism to change a lateral relative position between the probe head and the sample to direct the second portion to different locations of the sample.

56. A method for optically measuring a sample, comprising:

directing light in a first propagation mode to a vicinity of a sample under measurement;

directing a first portion of the light in the first propagation mode to propagate away from the sample at the vicinity of the sample without reaching the sample;

directing a second portion of the light in the first propagation mode to the sample to cause reflection at the sample;

controlling reflected light from the sample to be in a second propagation mode that is independent from the first propagation mode to co-propagate with the first portion along a common optical path; and

using the first portion in the first propagation mode and the reflected light in the second propagation mode to obtain information of the sample.

57. The method as in claim 56, further comprising using at least one optical waveguide to guide light.

58. The method as in claim 56, further comprising using at least one optical fiber to guide light.

59. The method as in claim 56, wherein the first and the second propagation modes are polarization modes.

60. The method as in claim 56, further comprising using a tunable optical bandpass filter to filter the light before to the light reaches the vicinity of the sample to select a spectral response of the sample to measure.

61. The method as in claim 56, further comprising using a tunable optical bandpass filter to filter the first portion in the first propagation mode and the reflected light in the second propagation mode to select a spectral response of the sample to measure.

62. An apparatus for optically measuring a sample, comprising:

a) a light source;

b) a waveguide supporting at least first and second independent propagation modes and guiding the light radiation from the light source in the first propagation mode to the vicinity of a sample under examination;

c) a probe head that terminates the waveguide in the vicinity of the sample and reverses the propagation direction of a portion of the first propagation mode in the waveguide while transmitting the remainder of the light radiation to the sample, the probe head operable to convert reflected light from the sample into the second propagation mode;

d) a differential delay modulator that transmits the light in both the first and the second propagation modes from the probe head and the waveguide and varies the relative optical path length between the first and the second propagation modes;

e) a mode combiner to receive light from the differential delay modulator and operable to superpose the first and the second propagation modes by converting a portion of each mode to a pair of new modes;

f) at least one photodetector to receive light in at least one of the two new modes; and

g) an electronic controller in communication with the photodetector and operable to extract information of the sample from the output of the photodetector.

63. The apparatus as in claim 62, wherein the electronic controller is in communication with and operates to control the differential delay modulator.

64. The apparatus as in claim 62, wherein the electronic controller is in communication with and operates to control the probe head.

65. The apparatus as in claim 62, further comprising a tunable optical bandpass filter located to filter either light to the probe head or light from the probe head to select a spectral response of the sample to measure.

66. An apparatus for optically measuring a sample, comprising:

a first waveguide capable of maintaining at least one propagation mode;

a light source that emits radiation to excite the propagation mode in the first waveguide;

a light director that terminates the first waveguide with its first port and passes the light mode entering the first port, at least in part, through a second port and passes the light modes entering the second port, at least in part, through a third port;

a second waveguide that supports at least two independent propagation modes and having a first end coupled to the second port and a second end;

a probe head coupled to the second end of the second waveguide and operable to reverse the propagation direction of the light in part back to the second waveguide and to transmit the remainder to the sample, the probe head further operable to transform the collected light from the sample reflection to an orthogonal mode supported by the second waveguide and direct light in the orthogonal mode into the second waveguide;

a third waveguide supporting at least two independent propagation modes and being connected to the third port of the light director to receive light therefrom;

a differential delay modulator that connects to the third waveguide to receive light from the second waveguide and imposes a variable phase delay and a variable path length on one mode in reference to the other;

a fourth waveguide supporting at least two independent modes and coupled to the differential delay modulator to receive light therefrom; and

a detection subsystem positioned to receive light from the fourth waveguide and to superpose the two propagation modes from the fourth waveguide to form two new modes, mutually orthogonal, the detection subsystem comprising two photo-detectors respectively receiving light in the new modes.

67. The apparatus as in Claim 66, wherein the first, second, third and fourth waveguides are polarization-maintaining optical fibers supporting two orthogonal polarization modes.

68. The apparatus as in Claim 66, wherein the probe head comprises an uncoated or coated termination of a polarization-maintaining fiber to have a finite reflectance, a lens and a quarter-wave plate or a Faraday rotator arranged in a series.

69. The apparatus as in Claim 66, wherein the differential delay modulator comprises at least one segment of a tunable birefringent material and at least one segment of a fixed birefringent material.

70. The apparatus as in claim 69, wherein the tunable birefringent material comprises a liquid crystal material.

71. The apparatus as in claim 69, wherein the tunable birefringent material comprises a lithium niobate crystal.

72. The apparatus as in claim 69, wherein the fixed birefringent material comprises quartz or rutile.

73. The apparatus as in Claim 66, wherein the differential delay modulator comprises means for separating received light by modes and directing one mode through a fixed path while directing the other mode through a variable path length device.

74. The apparatus as in claim 73, wherein the variable path length device comprises:

a beam splitter to receive a light beam to be delayed and to transmit a portion of the light beam;

a transparent plate to receive transmitted light from the beam splitter and to rotate to change a path length of the transmitted light; and

a mirror to reflect light transmitted through the transparent plate back to the transparent plate to reach the beam splitter which reflects light coming from the transparent plate as a delayed output.

75. The device as in claim 73, wherein the variable path length device comprises:

an optical circulator to receive an input light beam to be delayed at a first port and to direct the input light beam to a second port,

a transparent plate to receive light from the second port of the optical circulator and to rotate to change a path length of the light transmitting therethrough; and

a mirror to reflect light transmitted through the transparent plate back to the transparent plate to reach the second optical port of the optical circulator which directs light from the second port to a third port as a delayed output.

76. The apparatus as in Claim 73, wherein the variable path length device comprises a piezoelectric stretcher of a polarization-maintaining optical fiber.

77. The apparatus as in Claim 73, wherein the variable path length device comprises two collimators both facing a mechanically movable retroreflector in such a way that the collimated light from one collimator is collected by the other through a trip to and from the retroreflector.

78. The apparatus as in Claim 73, wherein the variable path length device comprises two collimators optically linked through double passing a rotatable optical plate and bouncing off a reflector.

79. The apparatus as in Claim 66, wherein the light director is a polarization-preserving circulator that conveys a mode supported by the first waveguide to one of the modes supported by the second waveguide and conveys the independent modes supported by the second

waveguide to the corresponding independent modes supported by the third waveguide.

80. The apparatus as in claim 66 wherein the light director comprises:

a) a polarization-maintaining circulator that conveys a polarization mode entering a first port to a second port, causing no change in the state of polarization, and conveys the polarization mode entering the second port to a third port, causing no change in the state of polarization;

b) a first polarizing beam splitter that is connected to the second port of the polarization-maintaining circulator and separates the light into two different paths by state of polarization; and

c) a second polarizing beam splitter that is connected to the third port of the polarization-maintaining circulator and separates the light into two different paths by state of polarization.

81. The apparatus as in Claim 66, wherein the light director is a polarization-insensitive beam splitter.

82. The apparatus as in Claim 66, wherein the detection subsystem comprises a polarizing beam splitter oriented in such a way that each split radiation is a superposition of the two independent propagation modes in the fourth waveguide and is received by a photo-detector.

83. The apparatus as in claim 66, further comprising a tunable bandpass filter in one of the first, the second, the third, and fourth waveguides to filter light.

84. A device, comprising:

an optical waveguide to guide an optical radiation in a first optical mode;

an optical probe head coupled to the optical waveguide to receive the optical radiation, the optical probe head operable to (1) redirect a portion of the optical radiation back to the optical waveguide while transmitting the remaining radiation to a sample, (2) receive and direct the reflected or backscattered radiation from the sample into the waveguide, and (3) control the reflected or the backscattered light from the sample to be in a second optical mode different from the first optical mode; and

an optical detection module to receive the radiation redirected by the probe head through the waveguide and to convert optical radiation in the first and second optical modes, at least in part, into a common optical mode.

85. The device as in claim 84, wherein the optical waveguide comprises an optical fiber.

86. The device as in claim 84, wherein the optical waveguide comprises a polarization maintaining fiber.

87. The device as in claim 84, further comprising a differential delay device in an optical path between the optical probe head and the optical detection module to modulate the relative optical path length of the two propagation modes.

88. A device for optically measuring a sample, comprising:

an input waveguide, which supports first and second different propagation modes, to receive and guide an input beam in the first propagation mode;

an output waveguide, which supports first and second different propagation modes;

a probe head coupled to the input waveguide to receive the input beam and to the output waveguide to export light, the probe head operable to direct a first portion of the input beam in the first propagation mode into the output waveguide and direct a second portion of the input beam to a sample, the probe head collecting reflection of the second portion from the sample and exporting to the output waveguide the reflection as a reflected second portion in the second propagation mode; and

a detection module to receive the reflected first portion and the reflected second portion in the output waveguide and to extract information of the sample carried by the reflected second portion.

89. The device as in claim 88, wherein the input and output waveguides are polarization maintaining fibers.

90. The device as in claim 88, further comprising a tunable optical bandpass filter positioned to filter the light received by the detection module.

91. A method, comprising:

guiding optical radiation in both a first propagation mode and a second, different propagation mode through an optical waveguide towards a sample;

directing radiation in the first propagation mode away from the sample without reaching the sample;

directing radiation in the second propagation mode to interact with the sample to produce returned radiation from the interaction;

coupling both the returned radiation in the second propagation mode and the radiation in the first propagation mode into the optical waveguide away from the sample; and

using the returned radiation in the second propagation mode and the radiation in the first propagation mode from the optical waveguide to extract information of the sample.

92. The method as in claim 91, wherein the first propagation mode and the second propagation mode are two polarization modes that are orthogonal to each other.

93. The method as in claim 92, wherein the first propagation mode and the second propagation mode are two orthogonal linear polarization modes.

94. The method as in claim 91, wherein the waveguide is a polarization maintaining fiber.

95. The method as in claim 91, further comprising adjusting a relative phase delay between the radiation in the first propagation mode and the radiation in the second propagation mode that are directed in the optical waveguide away from the sample to select a layer of the sample to measure.

96. The method as in claim 95, further comprising modulating the relative phase delay at a modulation frequency in measuring the sample.

97. The method as in claim 95, further comprising:

adjusting the relative phase delay to a first value to measure a first signal associated with a first layer within the sample;

adjusting the relative phase delay to a second, different value to measure a second signal associated with a second layer within the sample; and

obtaining a ratio between the first and the second signals to extract information about a layer of the sample located between the first and the second layers.

98. The method as in claim 97, further comprising using a tunable optical bandpass filter to filter the radiation to obtain a spectral response of the layer of the sample located between the first and the second layers.

99. The method as in claim 97, further comprising using the ratio to measure a concentration of glucose in a dermis layer of a skin tissue when used as the sample.

100. The method as in claim 91, further comprising controlling a spectral property of the radiation in the first and the second propagation modes to obtain spectral information of the sample.

101. The method as in claim 91, further comprising using a tunable optical bandpass filter to select a center wavelength of a spectral range of the radiation to the sample to obtain a spectral response of the sample in the spectral range.

102. The method as in claim 91, further comprising using a tunable optical bandpass filter to select a center wavelength of a spectral range of the radiation directed through the waveguide away from the sample to obtain a spectral response of the sample in the spectral range.

103. The method as in claim 91, further comprising:

mixing energy of the first propagation mode and the second propagation mode to produce a first optical signal and a second optical signal; and

detecting the first and second optical signals to extract the information of the sample.

104. The method as in claim 103, further comprising using a difference between the first optical signal and the second optical signal to extract the information of the sample.

105. The method as in claim 104, further comprising:

modulating a relative phase delay between the radiation in the first propagation mode and the radiation in the second propagation mode that are directed in the optical waveguide away from the sample at a modulation frequency; and

using information on amplitudes of the difference at the modulation frequency and a harmonic of the modulation frequency to extract the information of the sample.

106. The method as in claim 103, further comprising:

separating different optical spectral components in the first optical signal;

measuring the different optical spectral components in the first optical signal;

separating different optical spectral components in the second optical signal;

measuring the different optical spectral components in the second optical signal; and

using the measurements to obtain a spectral response of the sample at a spectral component selected from the different optical spectral components.

107. The method as in claim 106, further comprising using an optical grating to separate the different optical spectral components in the fist optical signal by optical diffraction.

108. The method as in claim 91, further comprising:

adjusting a relative phase delay between the radiation in the first propagation mode and the radiation in the second propagation mode that are directed in the optical waveguide away from the sample to a value to select a layer from which a reflection component in the returned radiation in the second propagation mode substantially matches the radiation in the first propagation mode in phase;

modulating the relative phase around the value at a modulation frequency to obtain a measurement; and

processing the measurement to obtain information on the layer.

109. The method as in claim 108, further comprising:

using an optical delay device to produce and adjust the relative phase delay; and

using an optical delay modulator to modulate the relative phase.

110. The method as in claim 91, further comprising adjusting a relative lateral position between the radiation in the second propagation mode and the sample to direct the radiation to reach different locations on the sample to obtain information at the different locations.

111. The method as in claim 91, further comprising converting the optical radiation in the first and the second propagation modes, at least in part, to a pair of new propagation modes; and

detecting the intensities of the pair of the new propagation modes to extract information about the sample.

112. The method as in claim 91, wherein the first and the second propagation modes are two orthogonal linear polarization modes, the method further comprising:

using a polarizer to partially mix the first and the second propagation modes to produce an optical signal in a new linear polarization mode; and

detecting the optical signal to obtain the information of the sample.

113. A device for optically measuring a sample, comprising:

a waveguide, which supports a first propagation mode and a second, different propagation mode, to receive and guide an input beam in both the first and the second propagation modes;

a probe head coupled to the waveguide to receive the input beam and to reflect a first portion of the input beam in the first propagation mode back to the waveguide in the first propagation mode and direct a second portion of the input beam in the second propagation mode to a sample, the probe head collecting reflection of the second portion from the sample and exporting to the waveguide the reflection as a reflected second portion in the second propagation mode; and

a detection module to receive the reflected first portion and the reflected second portion in the waveguide and to extract information of the sample carried by the reflected second portion.

114. The device as in claim 113, further comprising:

an optical delay device in an optical path of the reflected first and second portions to produce a relative phase delay between the reflected first and second portions; and

an optical delay modulator in the optical path of the reflected first and second portions to modulate the relative phase.

115. The device as in claim 113, further comprising an optical delay modulator in an optical path of the reflected first and second portions to produce a relative phase delay between the reflected first and second portions and to modulate the relative phase.

116. The device as in claim 113, further comprising a variable optical delay unit in an optical path of the reflected first and second portions to produce a variable relative phase delay between the reflected first and second portions, wherein the variable optical delay unit comprises:

a mode splitting unit to separate the reflected first portion in the first propagation mode and the second portion in the second propagation mode into a first optical path and a second optical path, respectively; and

a variable optical delay element in one of the first and the second optical paths to adjust an optical path length.

117. The device as in claim 116, wherein the variable optical delay element comprises:

a beam splitter to receive an input light beam to be delayed and to transmit a portion of the input light beam;

a transparent plate to receive transmitted light from the beam splitter and to rotate to change a path length of the transmitted light; and

a mirror to reflect light transmitted through the transparent plate back to the transparent plate to reach the beam splitter which reflects light from the transparent plate as a delayed output.

118. The device as in claim 116, wherein the variable optical delay element comprises:

an optical circulator to receive an input light beam to be delayed at a first port and to direct the input light beam to a second port,

a transparent plate to receive light from the second port of the optical circulator and to rotate to change a path length of the light transmitting therethrough; and

a mirror to reflect light transmitted through the transparent plate back to the transparent plate to reach the second optical port of

the optical circulator which directs light from the second port to a third port as a delayed output.

119. The device as in claim 116, wherein the variable path length element comprises a fiber and a fiber stretcher engaged to the fiber to change a length of the fiber.

120. The device as in claim 116, wherein the variable path length element comprises two optical collimators and a movable retro-reflector in an optical path linking the two optical collimators.

121. The device as in claim 116, wherein the variable path length element comprises two optical collimators, and an optical plate and a reflector in an optical path linking the two optical collimators, wherein the optical plate rotates to change a path length of light.

122. The device as in claim 113, further comprising a variable optical delay unit in an optical path of the reflected first and second portions to produce a variable relative phase delay between the reflected first and second portions, wherein the variable optical delay unit comprises at least one tunable birefringent material and at least one fixed birefringent material.

123. The device as in claim 122, wherein the tunable birefringent material comprises a liquid crystal.

124. The device as in claim 122, wherein the tunable birefringent material comprises an electro-optic birefringent material.

125. The device as in claim 113, wherein the detection module comprises an optical detector.

126. The device as in claim 125, wherein the detection module further comprises an optical polarizer to receive and mix the reflected first and second portions to produce an optical output to the optical detector.

127. The device as in claim 126, further comprising an electronic unit to process output from the optical detector and process the output to extract the information of the sample.

128. The device as in claim 113, wherein the detection module comprises:

an optical polarizing beam splitter to receive and mix the reflected first and second portions that are respectively in the first and the second propagation modes to produce a first optical signal and a second optical signal;

a first optical detector to receive the first optical signal;

a second optical detector to receive the second optical signal; and

an electronic unit to receive and process outputs from the first and the second optical detectors to extract the information of the sample.

129. The device as in claim 128, wherein the first and second optical detectors are first and second detector arrays, respectively, the device further comprising:

a first grating to receive and diffract the first optical signal;

a first lens to focus different diffraction components in the first optical signal to different locations on the first detector array;

a second grating to receive and diffract the second optical signal; and

a second lens to focus different diffraction components in the second optical signal to different locations on the second detector array.

130. The device as in claim 113, wherein the probe head comprises:

a mode-selective reflector to select the first portion of the input beam in the first propagation mode to reflect and to select the second portion of the input beam in the second propagation mode to transmit to the sample.

131. The device as in claim 130, wherein the first and the second propagation modes are orthogonal linear polarization modes, wherein the mode-selective reflector comprises:

a polarization beam splitter which transmits light in the second propagation mode to the sample and reflects light in the first propagation mode; and

a reflector positioned to reflect the light in the first propagation mode back to the polarization beam splitter.

132. The device as in claim 130, wherein the probe head further comprises a lens system between the waveguide and the mode-selective reflector.

133. The device as in claim 113, wherein the waveguide is a polarization maintaining waveguide.

134. The device as in claim 23, wherein the waveguide is a polarization maintaining fiber.

135. The device as in claim 113, further comprising:

a light source to produce the input beam;

an input waveguide to receive the input beam from the light source and to guide the input beam;

an output waveguide to receive the reflected first and second portions from the waveguide and to direct the reflected first and second portions to the detection module; and

an optical router coupled to the input waveguide, the waveguide, and the output waveguide and operable to direct light coming from the input waveguide to the waveguide and to direct light coming from the waveguide to the output waveguide.

136. The device as in claim 135, wherein the optical router is an optical circulator.

137. The device as in claim 135, wherein the optical router is a polarization preserving optical circulator.

138. The device as in claim 135, further comprising a tunable optical filter located in one of the input waveguide, the waveguide, and the output waveguide to select a portion of the spectral response of the sample to measure.

139. The device as in claim 113, further comprising a tunable optical filter to filter the input beam to select a portion of the spectral response of the sample to measure.

140. The device as in claim 113, further comprising a tunable optical filter to filter the reflected first and second portions to select a portion of the spectral response of the sample to measure.

141. The device as in claim 113, further comprising a mechanism to change a lateral relative position between the probe head and the sample to direct the second portion to different locations of the sample.

142. A device for optically measuring a sample, comprising:

an input waveguide, which supports a first propagation mode and a second, different propagation mode, to receive and guide an input beam in both the first and the second propagation modes;

an output waveguide, which supports the first and the second propagation modes;

a probe head coupled to the input waveguide to receive the input beam and to the output waveguide, the probe head operable to direct a first portion of the input beam in the first propagation mode into the output waveguide in the first propagation mode and direct a second portion of the input beam in the second propagation mode to a sample, the probe head collecting reflection of the second portion from the sample and exporting to the output waveguide the reflection as a reflected second portion in the second propagation mode; and

a detection module to receive the reflected first portion and the reflected second portion in the output waveguide and to extract information of the sample carried by the reflected second portion.

143. The device as in claim 142, further comprising:

an optical delay device in an optical path of the reflected first and second portions to produce a relative phase delay between the reflected first and second portions; and

an optical delay modulator in the optical path of the reflected first and second portions to modulate the relative phase.

144. The device as in claim 142, further comprising an optical delay modulator in an optical path of the reflected first and second portions to produce a relative phase delay between the reflected first and second portions and to modulate the relative phase.

145. The device as in claim 142, further comprising a variable optical delay unit in an optical path of the reflected first and second portions to produce a variable relative phase delay between the reflected first and second portions, wherein the variable optical delay unit comprises:

a mode splitting unit to separate the reflected first portion in the first propagation mode and the second portion in the second

propagation mode into a first optical path and a second optical path, respectively; and

a variable optical delay element in one of the first and the second optical paths to adjust an optical path length.

146. The device as in claim 142, wherein the detection module comprises:

an optical polarizing beam splitter to receive and mix the reflected first and second portions that are respectively in the first and the second propagation modes to produce a first optical signal and a second optical signal;

a first optical detector to receive the first optical signal;

a second optical detector to receive the second optical signal; and

an electronic unit to receive and process outputs from the first and the second optical detectors to extract the information of the sample.

147. The device as in claim 146, wherein the first and second optical detectors are first and second detector arrays, respectively, the device further comprising:

a first grating to receive and diffract the first optical signal;

a first lens to focus different diffraction components in the first optical signal to different locations on the first detector array;

a second grating to receive and diffract the second optical signal; and

a second lens to focus different diffraction components in the second optical signal to different locations on the second detector array.

148. The device as in claim 142, wherein the probe head comprises:

a mode-selective reflector to select the first portion of the input beam in the first propagation mode to reflect and to select the second portion of the input beam in the second propagation mode to transmit to the sample.

149. The device as in claim 148, wherein the first and the second propagation modes are orthogonal linear polarization modes, wherein the mode-selective reflector comprises:

a polarization beam splitter which transmits light in the second propagation mode to the sample and reflects light in the first propagation mode; and

a reflector positioned to reflect the light in the first propagation mode back to the polarization beam splitter.

150. The device as in claim 148, wherein the probe head further comprises a lens system between the waveguide and the mode-selective reflector.

151. The device as in claim 142, wherein the waveguide is a polarization maintaining waveguide.

152. The device as in claim 142, wherein the waveguide is a polarization maintaining fiber.

153. The device as in claim 142, further comprising a tunable optical filter located in one of the input waveguide and the output waveguide to select a portion of the spectral response of the sample to measure.

154. The device as in claim 142, further comprising a mechanism to change a lateral relative position between the probe head and the sample to direct the second portion to different locations of the sample.

155. A device for optically measuring a sample, comprising:

a waveguide, which supports at least an input propagation mode of light, to receive and guide an input beam in the input propagation mode;

a probe head coupled to the waveguide to receive the input beam and to reflect a first portion of the input beam back to the waveguide in the input propagation mode and direct a second portion of the input beam in the input propagation mode to a sample, the probe head collecting reflection of the second portion from the sample and exporting to the waveguide the reflection as a reflected second portion in the input propagation mode; and

a detection module to receive the reflected first portion and the reflected second portion in the input propagation mode from the waveguide and to extract information of the sample carried by the reflected second portion.

156. The device as in claim 155, wherein the detection module comprises:

a beam splitter to split received light into a first beam and a second beam;

a first optical path to receive the first beam;

a second optical path to receive the second beam;

a beam combiner optically coupled to the first and the second optical paths to combine the first and second beams and to split the combined beam into a first output beam in a first propagation mode and a second output beam in a second propagation mode;

a first optical detector to receive the first output beam; and

a second detector to receive the second output beam.

157. The device as in claim 156, wherein the detection module comprises a variable optical delay element in the second optical path to adjust a relative delay between the first and the second beams at the beam combiner.

158. The device as in claim 156, wherein the beam combiner is a polarization beam splitter and the first and the second propagation modes are two orthogonal polarization modes.

159. The device as in claim 155, wherein the optical probe head comprises an optical partial reflector which reflects the first portion of the input beam back to the waveguide.

160. The device as in claim 155, further comprising a tunable optical filter in an optical path of light to tune the frequency of the first and second output beams to measure the sample with a spectral bandwidth of the filter.

161. The device as in claim 155, further comprising a positioning mechanism coupled to adjust a relative lateral position between the optical probe head and the sample to direct the second portion to reach different locations on the sample to obtain information of the sample at the different locations.